ABSTRACT

Background: Airway management procedures are critical for emergency medicine (EM) physicians, but rarely performed skills in pediatric patients. Worldwide experience with respect to frequency and confidence in performing airway management skills has not been previously described.

Objectives: Our aims were 1) to determine the frequency with which pediatric emergency medicine physicians perform airway procedures including: bag-mask ventilation (BMV), endotracheal intubation (ETI), laryngeal mask airway (LMA) insertion, tracheostomy tube change (TTC), and surgical airways, and 2) to investigate predictors of procedural confidence regarding advanced airway management in children.

Methods: A web-based survey of senior pediatric emergency physicians was distributed through the six research networks associated with Pediatric Emergency Research Network (PERN). Physicians were queried regarding their most recent clinical experience performing or supervising airway procedures, as well as with hands on practice time or procedural teaching. Responses were dichotomized to within the last year, or ≥ 1 year. Confidence was assessed using a Likert scale for each procedure, with results for ETI and LMA stratified by age. Response levels were dichotomized to "not confident" or "confident." Multivariate regression models were used to assess relevant associations.

Results: 1602 of 2446 (65%) eligible clinicians at 123 PERN sites responded. In the previous year, 1297 (85%) physicians reported having performed bag-mask ventilation, 900 (59%) had performed intubation, 248 (17%) had placed a laryngeal mask airway, 348 (23%) had changed a tracheostomy tube, and 18 (1%) had performed a surgical airway. Of respondents, 13% of

physicians reported the opportunity to supervise but not provide ETI, 5% for LMA and 5% for BMV. The percentage of physicians reporting "confidence" in performing each procedure was: BMV (95%) TTC (43%), and surgical airway (16%). Clinician confidence in ETT and LMA varied by patient age. Supervision of an airway procedure was the strongest predictor of procedural confidence across airway procedures.

Conclusion: BMV and ETI were the most commonly performed pediatric airway procedures by emergency medicine physicians, and surgical airways are very infrequent. Supervising airway procedures may serve to maintain procedural confidence for physicians despite infrequent opportunities as the primary proceduralist.

INTRODUCTION

The ability to successfully perform critical procedural skills is fundamental to the care of seriously ill and injured children. Effective management of the pediatric airway is central to such resuscitative efforts. Pediatric arrest more commonly results from respiratory rather than cardiac etiology, and therefore early and effective airway management can be life-saving.[1]

Critical illness and injury occurs less commonly in children than in adults.[2–5] Data suggest that the need for endotracheal intubation in pediatric patients presenting to the emergency department (ED) ranges from 0.6 to 3.3 cases per thousand visits.[6,7] Therefore, clinical opportunities for emergency medicine (EM) physicians to manage pediatric airways may be limited. For EDs seeing small volumes of children, the absolute number of airway procedures performed will therefore be very low. Even for high volume pediatric EDs, including tertiary care children's hospitals, clinical opportunities are often directed first toward those in training, or divided amongst a large number of practicing EM physicians or other airway specialists.[8] The result is a relative paucity of clinical opportunities to manage pediatric airways, with the potential for long intervals during which such airway management skills are not utilized.[8,9]

Prior investigations have aimed to determine how frequently EM physicians perform airway management skills in children. Available data comes largely from investigations that provide single center estimates or focus on institutional rather than physician level experience.[7–13] One study surveyed pediatric emergency medicine (PEM) physicians throughout the United States, but had a relatively low survey response rate and did not include physicians in other parts of the world.[14] In addition, prior queries have not captured experience across the entire spectrum of airway management procedures.

The relative infrequency of clinical experiences including pediatric airway procedures may also negatively impact the confidence of EM physicians. Surveys of clinicians who care for children in the emergency setting suggest that maintenance of airways skills is perceived to be important, however inadequate clinical opportunities result in a lack of comfort with pediatric airway management.[7,14,15] The relationship between clinical experience and procedural confidence with regard to pediatric airway procedures has not been well defined.

OBJECTIVES

Our primary objective was to assess the clinical experience of practicing EM physicians with pediatric airway procedures, including: bag-mask ventilation (BMV), endotracheal intubation (ETI), laryngeal mask airway (LMA) insertion, tracheostomy tube change (TTC), and surgical airways. Our secondary objective was to investigate EM physicians' confidence in their ability to perform these procedures, and to determine predictors of such confidence.

METHODS

Study Design

This was an international, multicenter, cross-sectional survey study of senior practicing EM physicians working in EDs affiliated with Pediatric Emergency Research Networks (PERN).[16]

Setting

Participating hospitals were affiliated with one of the following research networks: Pediatric Emergency Medicine Collaborative Research Committee (PEM-CRC, USA), Pediatric

Emergency Care Applied Research Network (PECARN, USA), Pediatric Emergency Research Canada (PERC, Canada), Pediatric Emergency Research in the United Kingdom & Ireland (PERUKI, UK & Ireland), Pediatric Research in Emergency Departments International Collaborative (PREDICT, Australia and New Zealand), Research in European Pediatric Emergency Medicine (REPEM, Europe and the Middle East), and Red de Investigación y Desarrollo de la Emergencia Pediátrica de Latinoaméricana (RIDEPLA, South America).

Survey Development

Representative investigators from each network collaboratively determined key information to be collected, as well as survey structure and design. A list of critical procedures, both airway and non-airway, were selected for inclusion through investigator contribution and a review of relevant literature and resuscitation textbooks.[4,7,8] This investigation focused on the five airway procedures: BMV, ETI, placement of a LMA, TTC, and performance of any type of surgical airway.

Using an iterative process, question content and instrument organization were revised and refined, with a focus on balancing survey length and importance of data to be collected. The final survey included 31 questions designed to collect information including: demographics, postgraduate training background (EM, pediatrics, and/or PEM), hours of clinical work, proportion of clinical work in PEM, advanced life support training, most recent supervision and performance of the included procedures, opportunities for hands-on practice outside of clinical experience, as well as confidence in performing each procedure. The survey instrument was piloted by study investigators and 10 volunteers for additional input and estimation of time to

completion (approximately 10-15 minutes). Final revisions were made to enhance question clarity and organization.

Respondents were asked to report on the time since their most recent performance or supervision of each procedure by selecting from the following categories: within the last 3 months, within the last 6 months, within the last year, within the last 5 years, more than 5 years ago, or never. Procedural confidence was ranked on a 5-point Likert scale (1=not at all confident, 3=somewhat confident, and 5=confident). For the purposes of the present analyses, confidence scores were dichotomized into "confident" (score of 4 or 5 on the 5-point Likert scale) and "not confident" (3 or lower). For ETI and LMA, respondents were asked to rate their confidence across five different patient age groups: <3 months, 4-12 months, 1-5 years, 6-11 years, and ≥ 12 years. These scores were averaged for each respondent and the resulting mean was dichotomized into a binary confidence measure, as described above.

In addition to the individual physician survey, a separate site survey was developed to assess the operational characteristics and environment of care at each participating institution. Questions included: volume, staffing, trauma center designation, specialist availability, and presence of a pediatric intensive care unit.

Survey Distribution and Data Collection

Investigators from each of the six PERN networks nominated a site representative for each of the participating hospitals. Information about the study and an invitation to participate was emailed to each nominated site representative. The representative completed the site survey and distributed the physician survey to all eligible staff within the institution. Eligible staff included physicians working in a supervisory (senior) capacity, defined as those who work in the ED

without direct supervision at any time during their clinical practice. Given the breadth of hospitals included in this international study, we expected that the senior role would be fulfilled by different levels of staff in different hospital settings; therefore, after careful clarification of definitions, estimates were determined at the discretion of the institutional site representatives.

The surveys were administered electronically using SurveyMonkey (SurveyMonkey Inc., San Mateo, California, USA, www.surveymonkey.com), between April 2015 and March 2016. The time course for administration of the physician survey within each network was similar. Following the initial distribution, network representatives sent two reminders with active links to the survey at weekly intervals. No incentive was offered for survey participation.

Outcomes

Our primary outcome was the proportion of eligible PEM physicians that performed or supervised each of the airway procedures over defined periods of time. Our secondary outcome was physicians' confidence in performing each of these airway procedures.

Statistical Analysis

Physician demographic and hospital-level characteristics were described using frequencies with proportions for categorical variables, and medians with interquartile ranges for continuous variables. Data from partially completed surveys were included in the analysis, with numbers of responses provided for each outcome.

To assess our primary outcomes (i.e., the performance of critical pediatric airway procedures in the past year), we first calculated the prevalence of each with 95% confidence intervals (CIs). We then estimated a series of logistic regression models with each of the past-year performance

140 measures as the dependent variable. Based on consensus among the study investigators and
141 relevant literature,[7,14,15,17] we *a priori* selected the following physician demographic and
142 hospital-level characteristics for inclusion as independent variables: age, sex, average clinical
143 hours worked per week, primary training (EM or pediatrics), PEM specialty training, currently in
144 training, proportion of clinical time spent in pediatric emergency care (dichotomized to 0-99%
145 vs. 100%), geographic region, annual pediatric ED volume (patients aged 0-18 years), presence
146 of an ICU that accepts pediatric patients, and pediatric trauma designation. One model was
147 estimated for each of the following procedures: BMV, ETI, LMA, and TTC.

148 To assess our secondary outcomes (i.e., confidence in performing critical pediatric airway
149 procedures), we estimated another set of logistic regression models with each of the binary
150 confidence measures as the dependent variable. Given the potential for clinical and simulated
151 exposures, we chose *a priori* the following three measures of procedure-specific past-year
152 physician experience measures as the independent variables: performance, supervision, and
153 hands-on practice. One model was estimated for each procedure. In analyzing confidence, all
154 types of surgical airways (needle cricothyrotomy, Seldinger, and open technique) were
155 aggregated into a single measure by taking the average confidence score for each respondent and
156 dichotomizing the resulting mean into a binary confidence measure, as described above. For all
157 regression models, a robust variance estimator was used to accommodate the correlation
158 resulting from the clustering of respondents within hospitals.

159 All tests were two-tailed and alpha was set at 0.05. Data analyses were performed using Stata 14
160 (StataCorp LP, College Station, TX).

161 *Ethics Approval*

The survey was determined to be low-risk research and given ethical approval at the home site for data collection at Monash Health (Victoria, Australia). All other included sites gained either ethics approval or exemption status based on local institutional review boards, prior to survey distribution.

RESULTS

The survey was distributed to 2,446 eligible physicians in EDs across the six PEM research networks within PERN, with 1,602 (65.4%) respondents providing data on performance and confidence for any of the airway procedures. Table 1 provides an overview of the clinical settings and demographic data. Overall, 96 hospitals across fifteen countries were represented. Approximately half of the respondents practiced in North America. Of the 1,602 respondents 1,268 (79.2%) had completed post-graduate training (i.e. called specialists or attending physicians in different systems), 477 (29.8%) trained primarily in EM and 934 (58.3%) trained primarily in pediatrics. In total, 813 (50.8%) had completed or were currently completing specialty training in PEM. The vast majority (n=1,488; 92.9%) had been involved in some type of pediatric life support training within the last five years, either as an instructor or a participant.

The summary of our primary outcome, airway procedure experience, is presented in Figure 1. Within the last year, performance of BMV was most common (85.2%, 95% CI (83.3%, 87.0%)), followed by ETI (59.4% (56.8%, 61.9%)), TTC (23.2% (21.1%, 25.4%)), placement of a LMA (16.6% (14.7%, 18.6%)), and performance of a surgical airway (1.2% (0.1%, 1.9%)). Because of the infrequency of each of the individual surgical procedures performed within the last year (needle, n=5; percutaneous/Seldinger, n=5; and open, n=8) these results were combined and are

reported as a single procedure (surgical airway). When considering the lifetime performance of procedures, respondent rates were 6.8% for needle cricothyrotomy, 5.4% for percutaneous/Seldinger, and 4.4% for an open surgical airway. Physicians also gained additional exposure to airway procedures through supervision; 13.7%, 5.5%, and 5.4%, of physicians reported they had in the last year only supervised but not performed ETI, LMA and BMV, respectively.

The results of multivariable models predicting the past-year performance of airway procedures are presented in Table 2. Clinical time was the only consistently positive predictor across all of the included airway procedures. Geographic differences included higher adjusted odds of performing BMV in South America and significantly lower odds of ETI and LMA in Europe and Australia/New Zealand. Specialty qualification in PEM and current trainee status were significant predictors of performing the majority of the included airway procedures.

Our secondary outcome (confidence performing each airway procedure) is demonstrated in Figure 2. The proportion of clinicians who felt confident varied across the different airway procedures, from a high of 94.7% (95%CI, 92.4, 96.9) of respondents for BMV, to 8.1% (95%CI, 6.0, 10.3) for performing a surgical airway. Confidence was higher with increasing patient age; for ETT 2.2% increase per age group (95% CI 1.2, 3.2) and for LMA 5.2% increase per age group (95% CI 4.4, 6.0), as shown in Figure 3.

Supervision of an airway procedure within the last year was the strongest predictor of procedural confidence across airway procedures, with the exception of surgical airways. Performance of a procedure in the past year was a predictor of confidence for ETI, placement of an LMA and

TTC. Hands-on practice was a significant, independent predictor of confidence for all procedures except ETI (Table 3).

DISCUSSION

Emergency medicine physicians must be prepared to resuscitate ill and injured children, including timely performance of critical procedures when necessary. Perhaps the most important of these life-saving skills is the ability to manage the airway.[18,19] However, critical illness is relatively infrequent in children, limiting the exposure to such procedures for PEM physicians. Our study provides a broad evaluation of physician experience for several key emergency airway procedures at nearly 100 hospitals across 15 countries, including pediatric emergency physicians with primary training in EM and pediatrics. We found that opportunities to perform or supervise airway management procedures over a one-year period varied by procedure type, with the most common being BMV (>90%) and the least common being surgical airway procedures (<1%). Most (75%) of physicians had performed or supervised ETI in the preceding year. In addition, we identified predictors associated with increased airway procedure exposure, including site-specific factors such as region of the world, and physician-level characteristics including training status, clinical hours worked, and PEM specialty training. In addition, we were able to demonstrate a strong correlation between confidence in airway procedures and clinical exposure, which included either procedural performance or supervision. This finding has important implications for practicing physicians working in centers where they may be more likely to supervise trainees than actually perform these procedures themselves.

Others have similarly sought to establish the frequency with which airway procedures are performed or supervised by EM physicians. Mittiga et al. found that PEM physicians performed

147 intubations over one year in an pediatric tertiary care ED with a volume of 90,000 annual visits.[8] The median number of intubations performed by faculty members was 0 with a range of 0-5, although nearly 90% had supervised the procedure during the study year. Data on other airway management procedures were not included. In a pediatric tertiary care hospital in Canada with an annual ED volume of approximately 37,000 patients, less than 30 patients required intubation per year.[11] Attending physicians in PEM performed 29% of the airway procedures, PEM fellows 15%, residents 20%, with much of the remainder performed by pediatric intensive care unit (PICU) fellows. There were a small number of tracheostomy changes reported, and no one inserted an LMA or performed a surgical airway over the two-year study period. In three EDs (a community hospital, a secondary referral center, and a tertiary referral center) within an Australian network with a total combined annual volume of 55,000 visits, a total of 39 intubations were performed over a one-year period. There were no insertions of LMAs, TTCs, or surgical airways.[6] Across 5 urban general EDs in Scotland, an average of 3 pediatric intubations were performed at each center each year; data on the ED volume and the number of physicians working at each site was not included.[13] No other airway procedures were assessed. Losek et al. used survey methodology similar to ours to query 108 medical directors at pediatric EDs across the United States regarding frequency of intubation at an institutional level. Responses indicated great variation across sites, with a mean rate of 1.1-3.3 intubations per 1,000 visits. Included calculations suggested each PEM clinician would be perform and supervise less than 6 intubations per year.[7] No other airway procedures were assessed. More recently, a study using four years of data from a national database estimated that emergency physicians across a wide range of EDs in North America performed a pediatric ETI every 2.8 years.[9]

We found performance of invasive airway management to be uncommon in our study. Nearly half of the surveyed physicians in our study had not performed an ETI in the last year. The relatively lower odds of physicians having performed intubation outside of North America is interesting. Different practice patterns may exist across institutions or health care systems, which may be influenced by country or region. While we did not assess indications for intubation or other airway interventions, institutions or regions that more commonly utilize high-flow nasal cannula and non-invasive ventilation may have relatively fewer occasions for airway management procedures. Differences in staffing models and roles in airway management may also exist. For example, some hospitals utilize senior physicians only for cases in which assistance is required, whereas in other systems a senior physician is present for every airway procedure. Similarly, routine participation of anesthesiologists in airway management of ED patients has been shown to differ across countries and may contribute to varied airway procedure experience for PEM physicians, but was not specifically investigated in our study.[13,20,21] The increased odds of having performed invasive airway procedures for those in training is consistent with practice patterns in many institutions.[22] Although clinical exceptions may exist (e.g. known or suspected difficult airways), trainees are often encouraged to initially attempt airway procedures under careful supervision. Finally, we found that PEM specialty qualification increased the odds of performing most airway procedures. In EDs where PEM trained physicians are available, they are more likely to care for critically ill pediatric patients, and are therefore more likely to perform airway management procedures than those without such specialized training.

Regarding PEM physicians' confidence across pediatric airway procedures, we found associations between recent (within 1 year) performance of airway procedures and perception of

confidence by individual physicians. Physicians were also most confident with procedures performed most frequently and with the least associated risk (e.g. BMV) and least confident in those performed rarely and with highest associated risk (e.g. surgical airways). Interestingly, we found that confidence was not always associated with *performing* the procedure. Having *supervised* the procedure was associated with the highest adjusted odds of confidence across the airway procedures. Supervisors were more likely to be older, and age was a significant predictor of confidence. This may reflect more robust prior exposures in those who were supervising the procedures, Hands-on practice was the strongest predictor for confidence with surgical airways. Given the rarity with which this procedure is performed clinically, most surgical airway training involves simulation and airway models. Therefore, this association may reflect appropriate and recent skills training around this procedure. Importantly, these findings suggest that for those working in academic centers, supervising airway procedures or participating in hands on training through simulation or advanced life support courses may serve to maintain physician procedural confidence, even amongst the relative dearth of direct, hands-on clinical opportunities.

We sought to test associations between clinical exposure and confidence with regard to airway management. However, it is important to note that prior work has not consistently shown a correlation between procedural confidence and competence.[23,24] Although improved confidence can be helpful in high acuity situations such as airway management, a finding of improved confidence does not necessarily translate to improved likelihood of procedural success. A well known phenomenon from the psychology literature called the Dunning Kruger effect describes how people with relatively lower skill and experience are at greater risk of overestimating their own capabilities.[25] That is, those least likely to be successful are more likely to have inflated confidence.

Our study adds to the literature in several important ways regarding the assessment of airway exposure for senior EM physcians. First, our cross-sectional reach is greater than prior studies, including broad representation from physicians across 15 different countries. Second, we provide estimates for clinical exposures across the entire range of airway procedures, beyond ETI, including LMA placement, TTC, and surgical airways that were not obtained in prior studies. While these procedures are performed much less frequently than BMV or ETI, these are widely considered to be fundamental skills of EM physicians, and understanding frequency of exposure is important. Third, given the breadth of data collected, we were able to define rates of exposure, and interpret these through adjustments for relevant individual and institutional predictors. Finally, we were able to assess the relationship between clinical exposure and physician confidence for both frequently and infrequently performed airway procedures.

Limitations

Our study has some limitations. First, our survey methodology relied on self-report of procedural experience. We did not use clinical data or other means to confirm reported airway procedure exposure. For rare, high-acuity procedures such as surgical airways, physicians are likely to have vivid memories of when such patient care occurred; however for other more frequent airway procedures recall bias may influence responses. Second, we surveyed physicians about their airway management exposures, but did not focus on procedural outcomes. Opportunities to perform a given airway procedure does not equate with success, nor does more recent or more frequent exposure necessarily correlate with procedural competence. Finally, the hospitals included in the PERN networks are largely higher pediatric volume facilities, often with staffing models that include PEM specialists. However, the majority of emergent airway procedures in children occur at smaller, lower pediatric volume hospitals including community

and critical access settings. Therefore, our findings may not be generalizable to other clinical contexts.

Future Directions

Our study highlights the relative infrequency of clinical exposure to many airway procedures for senior practicing pediatric EM physicians. Prior surveys of PEM physicians have also recognized this paucity of ongoing procedural experience and suggested that clinical care alone may be insufficient to maintain these skills.[14] However, neither the optimal cumulative experience nor the frequency of exposure has been clearly defined. Studies have suggested the number of exposures required to achieve competence in intubation ranges from 37 to 200 attempts,[26–28] and efforts to understand the frequency of ongoing exposure required to maintain such skills are limited. In addition, there exists an opportunity to more broadly define competence beyond procedural success. The complex psychomotor skills might be assessed at a more granular level using approaches such as task analysis, and non-technical components including medical decision making around airway management and measurement of adverse events could also be included.

Therefore, future directions might aim to provide consensus around definitions of competence in airway management and the development of appropriate assessment tools. Such efforts could facilitate understanding of both learning and decay curves around these critical procedures. This might influence institutions and oversight bodies to develop requirements for ongoing certification or licensure. In addition, optimal educational strategies for maintenance of these

critical skills could be more readily assessed and promoted. Novel pedagogic approaches around didactic instruction,[29] simulation-based training,[30] and use of overhead video recordings from resuscitation bays or videolaryngoscopes have all been used to enhance airway training.[8,31] Using such effective educational strategies and offering training at appropriate frequencies could help address the identified gaps in clinical exposure and promote improved physician performance and ideally clinical outcomes for patients.

CONCLUSION

We report on airway procedural exposures for a wide sampling of senior EM physicians across the world. Apart from BMV, exposure to other emergency airway procedures in children was low. Notably, one quarter of senior EM physicians had not performed or supervised endotracheal intubation in the last year. Hands-on practice, performance or supervision of airway procedures were associated with increased procedural confidence; the strength of this association varied by procedure.

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